ASD TR-7-924(IV)

ASD INTERIM REPORT 7-924 (IV)
December 27, 1962

FIBER REINFORCEMENT OF METALLIC AND NONMETALLIC COMPOSITES

R.H. Baskey

CLEVITE CORPORATION
Mechanical Research Division

Contract AF 33(657)-7139
ASD Project 7-924

Interim Technical Engineering Report
17 July to 17 November, 1962

The elevated temperature (2000F) short time tensile strength of cobalt was increased from 2,700 psi to 23,700 psi by reinforcing the cobalt with 18 v/o of 5 mil continuous tungsten wires. This strengthening by 5 mil wires was equivalent to 89 percent of theoretical strengthening and was comparable to that attained by using the same quantity of 10 mil tungsten wire.

MANUFACTURING METHODS BRANCH
METHODS AND MATERIALS DIVISION
Aeronautical Systems Division
Air Force Systems Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

ABSTRACT-SUMMARY
Interim Progress Report

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Hot pressed cobalt containing a random distribution of discontinuous wires (10 mil, 5 mil or 2 mil cut into 1/8 or 1/4 inch lengths) were hot rolled into 0.050 inch sheet. Crack-free sheets were obtained from compacts containing up to 30 v/o of 5 mil wire and up to 20 v/o of 10 mil wire.

Hot rolled cobalt sheets (0.050 inch) containing 10, 20 or 30 volume percent of tungsten wire of either 10 mil, 5 mil or 2 mil diameter and lengths of 1/8 or 1/4 inch in a random pattern were weaker than pure cobalt at room temperature. However, at 2000F, the cobalt sheet containing a random pattern of tungsten wire was approximately twice as strong as pure cobalt sheet.

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NOTICES

FOREWARD

This interim technical report covers the period performed under contract AF 33(657)-7139 from 17 July 1962 to 17 November 1962. It is published for technical information only and does not necessarily represent the recommendations, conclusions, or approval of the Air Force.

This contract with Clevite Corporation, Mechanical Research Division, Cleveland, Ohio was initiated with ASD Manufacturing Methods, Project 7-924. It is administered under the direction of Mr. Lova Polley, (ASRCTB) Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

Mr. Raymond Baskey of the Mechanical Research Division of Clevite is the project engineer. Others who cooperated in the research and in the preparation of the report were: Mr. Arthur D. Schwope, Director, and Mr. Gail F. Davies, Manager.

The primary objective of the Air Force Manufacturing Methods Program is to increase productibility and improve the quality and efficiency of fabrication of aircraft, missiles, and components thereof. This report is being disseminated in order that methods and/or equipment developed may be used throughout industry, thereby reducing costs and giving "MORE AIR FORCE PER DOLLAR".

Your comments are solicited on the potential utilization of the information contained herein as applied to your present or future production programs. Suggestions concerning additional manufacturing methods development required on this or other subjects will be appreciated.

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PUBLICATION REVIEW

Approved by Gail F. Davies
Gail F. Davies, Manager
Aerospace Research Section

Approved by A. D. Schwope
A. D. Schwope, Director
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FIBER REINFORCEMENT OF METALLIC AND NON-METALLIC COMPOSITES

Interim Report No. IV

Contract AF 33(657)-7139

INTRODUCTION

The objective of this program is to establish parameters for the selection and application of fibers to the reinforcement of metal matrices and to demonstrate that this can be achieved through the fabrication of sheet and forged products.

ASD Report [1, 2] Numbers II and III discussed the studies to consolidate metals with metal wires by a powder metallurgy procedure. These consolidating techniques included hot pressing, cold pressing followed by sintering and hydrostatic pressing.

The work reported here is a continuation of the physical property evaluation, bonding studies, and consolidation studies of various systems. Initial additional experiments were performed on swaging and rolling of the composite material. Approval to proceed with Phase III was received on August 17, 1962. As a result, work will continue on many of these items and will include other forms of mechanical processing as proposed.

DISCUSSION

Procedure

ASD Report [1, 2] Numbers II and III described the procedures used in consolidating the wire and powder metal. These procedures are described briefly again.

1. Hot Pressing

   The hot pressing procedure furnished compacts with a density of 96 to 98 percent of theoretical. The wire diameters were 10, 5, 2, and 1 mil. These were used in lengths of 1/8 inch to 3 inches. The matrix materials consisted of nichrome, cobalt, stainless steel, and L605 (cobalt alloy). Three types of hot-pressed compacts were prepared. These were:

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[1] References are at end of text

a. 100 percent metal powder.
b. Metal powder plus random distribution of 1/8 to 1/2 inch length wires.
c. Metal powder plus continuous or discontinuous wires orientated parallel to the applied stress.
d. Metal powder plus continuous wires in alternate layers.

The continuous wires were laid out in separate layers and the metal powder was placed between each adjacent wire and between each layer.

Three types of compacts were hot pressed. These were for rolling, swaging, or forging. The compacts used for rolling were 3 inches by 1.875 inches by 0.385 inch. The initial forging compacts were a 2-inch diameter blank by 1 inch thick. The compacts for swaging were 5.2 inches by 2 inches by 0.5 inch.

The compacts were hot pressed in a graphite die at temperatures of 2000 F to 2300 F depending on the composition at pressures of 4,500 psi or 5,000 psi in either a hydrogen-argon atmosphere or vacuum.

2. Hot Rolling

Twelve hot-pressed compacts were used for experimental hot rolling studies. Some of these compacts were machined to fit into stainless steel picture frames. However, the majority of the compacts were used in the as-hot pressed condition (not machined). They were shrunk fit into frames and covered top and bottom with 0.062 inch thick stainless steel sheet. This assembly was welded completely around to prevent the compact from oxidizing during the hot rolling.

The compacts consisted of cobalt, cobalt plus a random distribution of tungsten wires, cobalt plus tungsten wires aligned in one direction and cobalt plus tungsten wires in alternate layers (each layer 0.008 inch apart and 90 degrees to the adjacent layer).

The hot "sheath" rolling was performed on a 2-high Stanat Mill with 5 inch diameter rolls. Most of the compacts were rolled in two stages. First, the compacts were hot rolled. Second, they were warm rolled. The hot sheath rolling phase consisted of heating the welded assemblies to 2000F for 20 minutes before the first pass, and 5 minutes between each successive pass. The material was transferred from the furnace to the rolling mill in the shortest time interval to minimize cooling. The rolls were heated by a gas flame to a temperature of 400 to 500F. The compact retained a greater amount of heat during each pass through the rolls when the rolls were preheated.

Table 1 is a detailed record of the rolling procedure used on compact 343. This compact consisted of 10 v/o tungsten wire (5 mil) cut into 1/8 inch lengths which was randomly dispersed in a cobalt matrix. Compact 343 was reduced approximately 15 percent on the first pass and about 20 percent on the succeeding passes. The cladding was stripped after 8 passes when the compact (core) had been reduced to 0.065 inch.

Next, the compact was warm rolled by heating (furnace temperature - 1000F) for 10 minutes before the first pass and 5 minutes between each succeeding pass. The purpose of warm rolling was to improve the surface finish and flatten the sheet material. The rolling schedule described in Table 1 for compact number 343 was typical for cobalt base composites. This type of rolling schedule may not apply on other types of compacts. For instance, a variation in the matrix material, fiber orientation, or fiber volume percent may require a change in the rolling practices.

TABLE 1 - Rolling Procedure Composite No. 343

Composition -

Wire - 10 v/o 5 mil diameter tungsten wire 1/8 inch length

Matrix- cobalt

Consolidation -	Wires and cobalt powder were blended by powder metallurgy techniques and hot pressed at 2300 F 1 hour at a load of 4,500 psi to furnish a composite which was 97 percent of theoretical density. Hot pressed size was 2.98 inches by 1.86 inches by 0.340 inch.
Assembly Method -	Compact or (core) was shrunk-fit into a stainless steel frame and clad top and bottom with 0.062 inch thick stainless steel. This assembly was welded completely around to prevent the compact from oxidizing.
Rolling Method -	Heat composite to 2000F for 20 minutes before the first pass and 5 minutes between each succeeding pass. Roll on 5 inch diameter 2 high Stanat Mill.

Table 1 - Cont'd - Hot Rolling No. 343

	Starting Thickness, inches			Finished Thickness, inches		Remarks
Pass	Composite	Core	% Red. approx.	Composite	Core	
1	.507"	.354"	15	.433"	.302"	
2	.433	.302	22	.340	.237	
3	.340	.237	22	.266	.185	
4	.266	.185	20.0	.213	.148	small break at one place on frame edge.
5	.213	.148	20.0	.170	.119	cladding bulging up from frame
6	.170	.119	20.0	.136	.095	curved plate
7	.136	.095	19.0	.110	.077	
8	.110	.077	15.0	.089	.065	tear in cladding beyond core, cladding rippled

Cladding stripped from frame. Core dimensions were 9.63 inch x 3.11 inch x 0.065 inch.

The next step was to warm roll by heating the core to **1000F for 10 minutes before the first pass and 5 minutes between passes.**

Warm Rolling No. 343

Pass	Starting Thickness, inches	Finished Thickness, inches	Remarks
1	.065"	.064"	flat
2	.064	.063	curled up slightly
3	.063	.061	flat
4	.061	.059	curved
5	.059	.057	flat
6	.057	.056	flat

Finished dimensions - 11.1 inches by 3.2 inches by .056 inch

Rolling Results

Twelve compacts were hot sheath rolled into sheet. The rolling experiments were designed to study the effect of rolling temperature and reduction rate on the fabricability of sheet containing discontinuous or continuous wires. The wire diameter, length, volume, and distribution were varied to evaluate their effect on the physical properties of rolled sheet. Specimens were taken from a number of the sheets for physical testing. The rolling experiments are still in process to determine the best rolling conditions for each type of compact.

Table 2 lists the fiber-metal compacts rolled into sheet. Sheet specimens have been selected for testing at room temperature and 2000F. The matrix material was cobalt. The tungsten wire used was 10 mil, 5 mil, and 2 mil diameter cut to lengths of 1/4 inch, 1/8 inch, and 3 inches. The wire content of these compacts was varied from 10 to 32 volume percent.

The rolled sheet containing a random distribution of 2 mil diameter tungsten wire exhibited the best surface appearance. There was no evidence of cracks on the surface or edges. The sheets containing a random distribution of 5 mil diameter tungsten wire cut to 1/8 inch lengths were also crack-free. Several of the sheets containing 10 mil diameter 1/8 to 1/4 inch tungsten wires showed edge cracks averaging 1/8 inch. Sheet number 329 containing 10 mil tungsten wire (30 v/o) cut to 1/4 inch showed cracks perpendicular to the rolling direction. When additional compacts containing 30 v/o of 10 mil tungsten are rolled, the rolling schedule will be changed to eliminate the surface cracking.

Two compacts (numbers 336 and 339) containing continuous 10 mil diameter tungsten wire embedded in a cobalt matrix were also rolled into 0.059 inch sheet. Compact 339 consisted of alternate layers of continuous 10 mil diameter tungsten wire. Each layer was 90 degrees to the adjacent layer and spaced 0.008 inch apart after rolling.

The rolled sheet from compact 339 was severely cracked perpendicular to the rolling direction in a number of locations. The long wires in compact 339 aligned parallel to the rolling direction were not elongating at the same rate as the matrix at this rolling temperature.

Table 2 - Rolling Results. Cobalt-Tungsten Wire Sheet

Matrix - Cobalt
Wire - Tungsten

Spec. No.	Wire Diameter	Wire Length	Wire V/o	Wire Orientation	Rolled Sheet Dimensions, inches	Comments
321	no wire	---	---	---	9.9" x 2.98" x .045"	Excellent
212	10 mil	1/8"	15.7	Random	11" x 2.4" x .061"	Edge cracks - surface laps
340	10 mil	1/8"	32	Random	9.1" x 3.1" x .055"	Edge cracks - 1/8 inch length
320	10 mil	1/8"	10	Random	10.2" x 3" x .049"	Good
325	10 mil	1/4"	20	Random	10.3" x 3" x .056"	Good
329	10 mil	1/4"	30	Random	8.2" x 3.1" x .067"	Cracking ⊥ to rolling direction across sheet - over 25% area
343	5 mil	1/8"	10	Random	11.1" x 3.2" x .056"	Good
341	5 mil	1/8"	20	Random	10" x 3.2" x .052"	Good
342	5 mil	1/8"	30	Random	8.8" x 3.1" x .058"	Good
345	2 mil	1/8"	10	Random	11.3" x 3.2" x .056"	Very good
339	10 mil	3"	21.9	Alternate layers	9.6" x 3" x .056"	Severe cracking ⊥ to rolling direction cracked every 1/2"
336	10 mil	3"	21.7	Aligned one direction	8.1" x 2.9" x .059"	Surface cracks ⊥ to rolling direction (penetrate cracks about .010")

The sheet fabricated from compact 336 (wires aligned perpendicular to the rolling direction) showed fine surface cracking parallel to the wire orientation. This type of cracking may have resulted from the reduction rate used at 2000F. Therefore, the rolling schedule will be changed when additional compacts similar to compact 336 are rolled.

Hot Pressed Properties

Table 3 shows the room temperature tensile properties of seven hot pressed compacts containing a matrix material of cobalt or nichrome. Three compacts were hot pressed under identical conditions to show the effect of wire diameter as a means of strengthening cobalt. The two compacts that contained wire had a wire content of 18 volume percent. The wires were continuous and aligned in the direction of applied stress. Compact 219 consisting of pure cobalt had a tensile strength of 56, 000 psi at room temperature and 2, 700 psi at 2000F. Compact 220 consisting of 5 mil diameter continuous tungsten wire in a cobalt matrix had a room temperature strength of 66, 000 psi. Hot pressed compact 225 containing 10 mil diameter continuous tungsten wire in a cobalt matrix had a room temperature strength of 77, 500 psi.

Elevated temperature data were reported[2] in ASD TR-7-924(III) for pure cobalt and tungsten wires. Elevated temperature tests at 2000F were made on hot pressed compact 220 (containing 5 mil tungsten wire). These elevated temperature tests indicated that the 5 mil wire strengthened the cobalt about the same amount as 10 mil tungsten wire. For instance, at 2000F hot pressed cobalt had a tensile strength of 2, 700 psi; cobalt plus 18 v/o of 10 mil tungsten wires had a tensile strength of 23, 600 psi; and cobalt plus 18 v/o of 5 mil tungsten wires had a tensile strength of 23, 700 psi. The strengthening achieved in the cobalt matrix at 2000F by using 18 v/o continuous tungsten wires was equivalent to 89 percent of theoretical strengthening.

Another series of experiments demonstrated the effect of wire orientation on strengthening hot pressed cobalt at room and elevated temperatures. Eighteen volume percent of 10 mil diameter tungsten wire was used in each compact. The wires in compact 225 were aligned in the direction of applied stress. This compact had a room temperature tensile strength of 77, 500 psi

TABLE 3

ROOM TEMPERATURE PHYSICAL PROPERTIES OF HOT PRESSED COMPOSITE MATERIAL

Spec. No.	Type Fiber	Fiber Diameter	Fiber Length	Vol. % Fibers	Fiber Orientation	Matrix Material	Hot Pressing Conditions	Ult. Tensile Str., psi	Yield Str.	Elong. % in 2" gage
219						Cobalt	2300F 1/2 hr. 4500 psi	56,000		
220	Tungsten (NF)	5 mil	3"	17.8	Continuous	Cobalt	2300F 1 hr. 5000 psi	66,000		
223	Tungsten (NF)	10 mil	1/8"	18.3	Random	Cobalt	2300F 1 hr. 5000 psi	37,000		
224	Tungsten (NF)	10 mil	1/2"	34.8	Random	Cobalt	2300F 1 hr. 5000 psi	25,000		
225	Tungsten (NF)	10 mil	3"	21.7	Continuous	Cobalt	2300F 1 hr. 5000 psi	77,500		0
226	Tungsten (NF)	10 mil	3"	21.9	Alternate	Cobalt	2300F 1 hr. 2000 psi	50,000	50,000	
227	Tungsten (NF)	10 mil	3"	17	Continuous	Nichrome	2250F 1 hr. 5000 psi	73,000		21.1

and an elevated temperature (2000F) tensile strength of 23, 500 psi. When the wires in each layer were aligned 90 degrees to the wires in an adjacent layer, i.e., compact 226, the compact strength was less than compact 225 (wires all aligned in one direction). For example, compact 226 had a tensile strength of 50, 000 psi at room temperature and 14, 800 psi at 2000F. At 2000F the hot pressed compact with tungsten wires aligned parallel to the applied stress were 9 times stronger than pure cobalt. Where the wires were in alternate layers and only one-half of the total wires were aligned parallel to the applied stress then the tensile strength at 2000F was 5.5 times stronger than pure cobalt. The strengthening at 2000F was equivalent to 46.7 percent of theoretical strengthening. The wires perpendicular to the applied stress in compact 226 had not contributed to the strengthening.

Sheet Properties

Table 4 lists the physical property data on hot rolled sheet composed of cobalt and discontinuous lengths of tungsten wires orientated in a random pattern. Three diameter tungsten wires were used, namely, 10 mil, 5 mil and 2 mil. The wire was cut into 1/4 and 1/2 inch lengths. The wire content was varied from 10 to 32 volume percent. The cobalt sheet containing a random wire pattern was weaker than pure cobalt at room temperature. For example, the pure cobalt rolled into 0.045 inch thick sheet had a room temperature strength of 112, 000 psi. The best sheet containing 2 mil random tungsten wires had a room temperature strength of 83, 000 psi. Sheet 212 had a tensile strength of 65, 200 psi at room temperature and 4, 510 psi at 2000F. This sheet was approximately twice as strong at 2000F as pure cobalt. Other tests are in process to determine the elevated tensile strength of pure cobalt sheet at 2000F and several of the sheets containing random 5 mil and 2 mil wires. Compacts are also being prepared for rolling into sheet which will contain discontinuous or continuous wires aligned in one direction. This latter type of sheet will demonstrate the effect of wire orientation on the properties of rolled sheet.

TABLE 4

ROOM TEMPERATURE PHYSICAL PROPERTIES OF HOT ROLLED COMPOSITE MATERIAL

Spec. No.	Type Fiber	Fiber Diameter	Fiber Length	Vol. % Fibers	Fiber Orientation	Matrix Material	Hot Pressed at	Hot Rolled at	Rolled Thickness	Ult. Tensile Str., psi	Yield psi	Elongation % in 2" gage
321						Cobalt	2300F 1 hr. 4, 500 psi	2000F	0.045	112,000	76,100	3
320	Tungsten (NF)	10 mil	1/4"	10	Random	Cobalt	" "	"	0.049	70,000	58,700	1.3
325	"	10 mil	1/4"	20	Random	Cobalt	" "	"	0.056	50,700	48,400	0.5
212B	"	10 mil	1/8"	15.7	Random	Cobalt	2300F-1 hr. 5,000 psi	"	0.061	65,200	55,700	0
340	"	10 mil	1/8"	32	Random	Cobalt	2300F 1 hr 4, 500 psi	"	0.055	49,600	47,000	1
343	"	5 mil	1/8"	10	Random	Cobalt	" "	"	0.056	79,000	57,400	1.8
341A	"	5 mil	1/8"	20	Random	Cobalt	" "	"	0.052	53,400	49,300	--
341B	"	5 mil	1/8"	20	Random	Cobalt	" "	"	0.052	73,100	68,100	--
342	"	5 mil	1/8"	30	Random	Cobalt	" "	"	0.058	79,000	76,000	1
345A	"	2 mil	1/8"	10	Random	Cobalt	" "	"	0.056	82,500	56,200	1.25
345B	"	2 mil	1/8"	10	Random	Cobalt	" "	"	0.056	83,000	59,400	2.2

Effect of Pretreating Wire Surfaces

Several items must be considered in selecting a metal wire for strengthening a high temperature metal or alloy. The items related to the tungsten wire surfaces are as follows:

(a) The tungsten wire will recrystallize at a lower temperature when in contact with many matrix materials. This will decrease the wire's strength.

(b) The tungsten wire may become embrittled at room temperature by being in contact with many matrix materials.

(c) The tungsten wire will react with some matrix materials to form a compound layer between the wire and matrix. In some instances these layers may be brittle at room temperature. However, the layers may be stronger and tougher than the wire or matrix at elevated temperatures.

Therefore, it was necessary to perform a series of experiments to study the effect of pretreating the tungsten wire surface on the composite physical properties.

On the majority of specimens tested to date, only one type of surface layer exerted any significant influence in strengthening the finished composite. This surface layer consisted of a plated layer of electroless cobalt on continuous tungsten wires which were embedded in stainless steel. Here the coated tungsten wire strengthened the stainless steel more than the uncoated tungsten wire at room temperatures. For instance, it was reported[2] in ASD TR-7-924 (III) that a cold pressed and sintered composite of stainless steel and continuous bare tungsten wires exhibited a tensile strength at room temperature of 48,000 psi while a stainless steel composite containing electroless cobalt-plated continuous 10 mil tungsten wires exhibited a room temperature tensile strength of 58,700 psi. The strengthening achieved by using coated continuous wire was equivalent to 80 percent of theoretical strengthening.

In several composites, all three of the items listed above may have influenced the composite's physical properties. However, as only a limited number of tests were conducted on each type of surface layer, it is not possible to establish how much each item contributed to the overall physical properties.

Several methods were investigated to improve the bond between the matrix and wire. Some of these were: (a) form a thin tungsten carbide (WC) layer on the tungsten wire as WC wets cobalt better than tungsten, (b) activate the tungsten wire surface with palladium chloride ($PdCl_2$), (c) plate tungsten wire with electroless cobalt, (d) sinter at a temperature near the matrix melting point to form a thicker diffusion layer.

Table 5 lists the specimens prepared to study the items discussed above. A series of test bars were prepared by using wires that had been carburized on the outer layer or coating the wires with a substance which would form a carbide layer simultaneously during the sintering operation. The tungsten wires were carburized at 1750F, 1800F, and 1950F to form tungsten carbide layers of 0.1 to 0.2 mil thickness. In addition, three types of solutions were used to coat the tungsten wires before they were embedded in the powder metal matrix. These coatings would form a tungsten carbide layer during the sintering operation. The solutions used were carbon black suspended in oleic acid, paraffin dissolved in carbon tetrachloride, glycerine and ethylene glycol.

Two wire patterns were used in evaluating the effect of a tungsten carbide surface layer in improving the bond between the wire and matrix. These patterns consisted of (a) continuous wires aligned in one direction throughout the entire specimen length, and (b) 1/2 inch length wires placed in a staggered pattern.

TABLE 5

EFFECT OF PRETREATING WIRE SURFACE ON ROOM TEMPERATURE PROPERTIES OF COMPOSITES

Spec. No.	Type Fiber	Fiber Diameter	Fiber Condition	Vol. % Fibers	Fiber Orientation	Matrix Material	Cold Pressed at tsi	Sintering Conditions	Ult. Tensile Str., psi	Elong. %
257						Cobalt	60	2300F - 1 hr - Vac	36,400	
258						Cobalt	60	2300F - 1 hr - H_2	55,500	
259						Cobalt	60	2300F - 1 hr - Vac	55,500	14
260						Cobalt	60	2300F - 1 hr - H_2	55,600	10
265	NF-W	10 mil	coated with carbon black	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - Vac	41,400	
266	NF-W	10 mil	coated with carbon black	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - H_2	52,000	
267	NF-W	10 mil	coated with paraffin in carbon tet.	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - Vac	42,000	
268	NF-W	10 mil	coated with paraffin in carbon tet.	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - H_2	52,700	
269	NF-W	10 mil	coated with glycerine	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - Vac	46,000	
270	NF-W	10 mil	coated with glycerine	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - H_2	49,300	
271	NF-W	10 mil	coated with ethylene glycol	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - Vac	40,000	
272	NF-W	10 mil	coated with ethylene glycol	2.1	1/2" pattern	Cobalt	60	2300F - 1 hr - H_2	50,600	
249	NF-W	10 mil	carburized at 1750F	17.3	Continuous	Cobalt	60	2300F - 1 hr - H_2	73,600	
250	NF-W	10 mil	carburized at 1800F	17.3	Continuous	Cobalt	60	2300F - 1 hr - H_2	73,100	2.5
251	NF-W	10 mil	carburized at 1900F	17.3	Continuous	Cobalt	60	2300F - 1 hr - H_2	62,900	2.5
261	NF-W	10 mil	carburized at 1750F	17.3*	1/2" staggered pattern	Cobalt	60	2300F - 1 hr - Vac	44,300	2.5
262	NF-W	10 mil	carburized at 1800F	17.3*	1/2" staggered pattern	Cobalt	60	2300F - 1 hr - Vac	34,700	
263	NF-W	10 mil	carburized at 1900F	2.1	1/2" staggered pattern	Cobalt	60	2300F - 1 hr - Vac	34,000	2.0
221	NF-W	10 mil	plated with electroless cobalt	17.3	Continuous	Cobalt	60	2300F - 1 hr - H_2	58,500	2.5
222	NF-W	10 mil	plated with electroless cobalt	17.3	Continuous	Cobalt	60	2300F - 1 hr - Vac	69,200	3.0
301	NF-W	10 mil	coated with glycerine	0.5	Continuous	Cobalt	60	2300F - 24 hrs - Vac	67,700	16.0
312	NF-W	10 mil	coated with $PdCl_2$	2.1	1/2" staggered	Cobalt	60	2300F - 1 hr - Vac	32,200	3.0
317	NF-W	10 mil	coated with $PdCl_2$	2.1	1/2" staggered	Cobalt	60	2300F - 1 hr - Vac	32,200	3.0

*Volume at fractured surface

Control specimens were produced by using uncoated wires in a cobalt matrix for comparison with the cobalt specimens containing coated wires. The wire patterns and consolidating techniques were identical for both types of specimens. Two specimens were fabricated by cold pressing for each type of coating. Then one of these specimens were sintered in vacuum while the other was sintered in hydrogen. The results in Table 5 indicate that the cobalt specimens containing 1/2 inch lengths of 2 v/o tungsten wires coated with carbon black, paraffin, glycerine or ethylene glycol were weaker than pure cobalt. A metallographic examination indicated that the glycerine coated wire had formed the best bond between the cobalt and tungsten wires.

Two cobalt specimens containing 2 v/o of 1/2 inch length tungsten wires coated with palladium chloride ($PdCl_2$) were also tested. This $PdCl_2$ coating was not satisfactory because it reacted with the tungsten wire and embrittled the wire during the sintering operation. Therefore, the specimen strength was not improved.

The tungsten wires which were carburized at 1750F, 1800F, and 1900F were used in a continuous wire pattern and 1/2 inch length staggered patterns. The best physical properties were obtained from specimens containing wires carburized at 1750F. This carburized wire strengthened the cobalt at room temperature but the degree of strengthening was less than that obtained from uncoated wires consolidated in the same manner. As an example, Specimen 249 with 17.3 v/o of 10 mil tungsten (carburized at 1750F) had a room temperature tensile strength of 73,600 psi as compared to pure cobalt which had a tensile strength of 55,600 psi. The specimen 210 reported [2] in ASD TR-7-924(III) containing 18 v/o of uncoated 10 mil tungsten wires had a room temperature tensile strength of 85,000 psi which was equivalent to 98 percent of theoretical strengthening.

Effect of Wire Orientation on Cold-Pressed-Sintered Bars

Table 6 lists data on cold pressed and sintered specimens that contained various percentages of 1/4 inch length 5 mil or 10 mil tungsten wires. These wires were randomly distributed in a cobalt matrix. The sintering temperature and times were varied from 2300F to 2550F and 1 hour to 24 hours respectively. All of the sintered specimens containing a random distribution of short wires were weaker at room temperature than pure cobalt. However, the data reported in another section indicated that the cobalt strength was doubled at 2000F when the cobalt contained a random distribution of 1/8 inch or 1/4 inch length 10 mil tungsten wires in hot pressed or rolled material.

Two stainless steel bars were also compared at room temperature. One bar contained 17.3 v/o of 10 mil continuous tungsten wires while the other bar contained 30 v/o of 10 mil 1/4 inch length tungsten wires in a random pattern. These were uncoated wires. The room temperature tensile strengths on these two sintered specimens were 39,200 psi for the continuous wire pattern and 17,500 psi for the random wire pattern.

Effect of Wire Overlaps on Composite Strength

Table 7 lists data on experiments to determine the effect of the overlap between adjacent wires. These data were preliminary and no conclusive results are yet available. Here ten wires were aligned parallel to each other in one plane at the center of the powder metal tensile bars. In the first group of specimens, the wires were 0.010 inch apart at the overlap area while the other group were 0.020 inch apart at the overlap area. Six specimens were prepared for each group with a different overlap in each specimen. These overlaps were 1/8, 1/4, 3/8, 3/4 and 1 inch.

TABLE 6

EFFECT OF WIRE ORIENTATION ON ROOM TEMPERATURE PROPERTIES OF COMPOSITES

Spec. No.	Type Fiber	Fiber Diameter	Vol. % Fibers	Fiber Orientation	Matrix Material	Cold Pressed at tsi	Sintering Conditions	Ult. Tensile Str., psi	Yield Str., psi	Elong. %	Comments
273	NF-W	10 mil	10	1/4" random	Cobalt	60	2300F - 1 Hr. Vac	29, 100	26, 400		
276	NF-W	10 mil	20	1/4" random	Cobalt	60	2300F - 1 Hr. Vac	24, 900			
278	NF-W	10 mil	30	1/4" random	Cobalt	60	2300F - 1 Hr. Vac	19, 500			
304	NF-W	10 mil	20	1/4" random	Cobalt	60	2550F - 24 Hrs - Vac	18, 200			
293	NF-W	10 mil	30	1/4" random	Cobalt	60	2550F - 24 Hrs - Vac	16, 400			
294	NF-W	5 mil	10	1/4" random	Cobalt	60	2550F - 24 Hrs - Vac	40, 800			
296	NF-W	5 mil	20	1/4" random	Cobalt	60	2550F - 24 Hrs - Vac	8, 300			
297	NF-W	10 mil	17.3	Continuous	Cobalt	60	2300F - 24 Hrs - Vac	65, 300			
298	NF-W				Cobalt	60	2300F - 24 Hrs - Vac	72, 300	27, 200	22	
310	NF-W	10 mil	17.3	Continuous	Stainless Steel	60	2460F - 4 Hrs - H_2	39, 200			
316	NF-W	10 mil	30	1/4" random	Stainless Steel	60	2460F - 4 Hrs - H_2	17, 300	16, 700		Uncoated Wire

TABLE 7

EFFECT OF WIRE OVERLAP ON ROOM TEMPERATURE PROPERTIES OF COMPOSITES

Spec. No.	Type Fiber	Fiber Diameter	Vol.% Fibers	Fiber Orientation	Matrix Material	Cold Pressed at tsi	Sintering Conditions	Ult. Tensile Str., psi	Elong. %	Comments
280	NF-W	10 mil	0.5	1/8" overlap between continuous	Cobalt	60	2300F - 1 Hr - Vac	45,000	6.5	0.010" between wire edges
281	NF-W	10 mil	0.5	1/4" " "	Cobalt	60	2300F - 1 Hr - Vac	45,900	7.5	" " "
282	NF-W	10 mil	0.5	3/8" " "	Cobalt	60	2300F - 1 Hr - Vac	50,300	9.0	" " "
283	NF-W	10 mil	0.5	1/2" " "	Cobalt	60	2300F - 1 Hr - Vac	49,400	9.0	" " "
284	NF-W	10 mil	0.5	3/4" " "	Cobalt	60	2300F - 1 Hr - Vac	50,800	10	" " "
285	NF-W	10 mil	0.5	1" " "	Cobalt	60	2300F - 1 Hr - Vac	49,400	7.5	" " "
286	NF-W	10 mil	0.5	1/8" " "	Cobalt	60	2300F - 1 Hr - Vac	46,400	6.5	.020" between wire edges
287	NF-W	10 mil	0.5	1/4" " "	Cobalt	60	2300F - 1 Hr - Vac	41,900	6.0	" " "
288	NF-W	10 mil	0.5	3/8" " "	Cobalt	60	2300F - 1 Hr - Vac	46,800	7.0	" " "
289	NF-W	10 mil	0.5	1/2" " "	Cobalt	60	2300F - 1 Hr - Vac	48,100	8.5	" " "
290	NF-W	10 mil	0.5	3/4" " "	Cobalt	60	2300F - 1 Hr - Vac	49,600	8.5	" " "
291	NF-W	10 mil	0.5	1" " "	Cobalt	60	2300F - 1 Hr - Vac	46,900	8.0	" " "
299	NF-W	10 mil	0.5	1/2" " "	Cobalt	60	2300F - 24 Hrs-Vac	66,400	15.0	" " "

Radiographic Results

The rolled sheets containing continuous or discontinuous wire patterns were radiographed to evaluate the effect of fabricating on fiber orientation and fiber stability. These are preliminary results obtained on ten sheets. The sheets contained the following wire patterns:

a. Cobalt sheet containing continuous 10 mil tungsten wire.
b. Cobalt sheet containing alternate layers (each layer aligned 90° to an adjacent layer) of tungsten wires.
c. Cobalt sheet containing discontinuous tungsten wires in a random pattern.

The radiographs indicated that the continuous wires in sheet 336 were unbroken. Here the rolling had been performed perpendicular to the wire alignment. The radiograph of the alternate layer sheet 339 indicated that the wires aligned parallel to the rolling direction had fractured into 1/16 or 1/8 inch lengths. The layers of wires perpendicular to the rolling direction were unbroken. Radiographs of the sheets containing 10 v/o random 10 mil or 5 mil wires in 1/8 or 1/4 inch lengths indicated that approximately 50 percent of the wires had aligned themselves in the rolling direction and that they had fractured into 1/16 or 1/32 inch lengths. The radiographs indicated that the major portion of the wires fracturing occurred in the wires aligned parallel to the rolling direction. Additional radiographs will be obtained to determine how this wire fracturing influences the physical properties.

CONCLUSIONS

1. Hot pressed cobalt was strengthened about the same degree by either 5 or 10 mil diameter continuous tungsten wires at either room temperature or 2000F.

2. Cobalt reinforced by continuous 5 mil tungsten wires was about 9 times stronger than pure cobalt at 2000F. This strengthening by 5 mil wire was equivalent to 89 percent of theoretical strengthening.

3. Cobalt sheet containing tungsten wire distributed in a random pattern was weaker at room temperature than pure cobalt. However, at 2000F, the cobalt containing a random pattern of wire was approximately twice as strong as the pure cobalt.

4. Hot pressed cobalt containing 21.9 v/o of alternate layers of continuous 10 mil tungsten wires (each layer 90° to an adjacent layer) was not strengthened at room temperature. However, at 2000F, this composite was 5.5 times stronger than pure cobalt. This strengthening at 2000F was equivalent to 46.7 percent of theoretical strengthening.

5. Hot pressed cobalt containing up to 30 v/o of discontinuous 5 mil tungsten wires could be hot rolled into crack-free 0.050 inch thick sheet. Hot pressed cobalt containing up to 20 v/o of discontinuous 10 mil tungsten wires could be rolled into 0.050 inch thick crack-free sheet.

6. An electroless cobalt coating on tungsten wire improved the bond strength between the wire and a stainless steel matrix. Other coatings on tungsten wire such as tungsten carbide, $PdCl_2$ and electroless nickel did not improve the bond strength.

7. Discontinuous wires in a random pattern provide strengthening in sheet or hot pressed material only at elevated temperatures.

8. Radiographs of sheets containing cobalt and a random distribution of discontinuous tungsten wires indicated that approximately 50 percent of the wires had aligned parallel to the rolling direction. Wires aligned in this direction had fractured into 1/16 or 1/32 inch lengths. Wires aligned perpendicular to the rolling direction were unbroken.

FUTURE WORK

1. Continue rolling experiments of composites containing wires.
2. Continue high temperature strength evaluation of hot pressed and rolled material.
3. Investigate forging properties of composites containing wires.
4. Prepare final report.

REFERENCES

Baskey, R. H. "Fiber Reinforcement of Metallic and Nonmetallic Composites," ASD Interim Report 7-924(II), May, 1962

Baskey, R.H. "Fiber Reinforcement of Metallic and Nonmetallic Composites," ASD Interim Report 7-924 (III), August 1962.

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Hot pressed cobalt containing a random distribution of discontinuous wires (10 mil. 5 mil or 2 mil cut into 1/8 or 1/4 inch lengths) were hot rolled onto 0.050 inch sheet. Crack-free sheets were obtained from compacts containing up to 30 v/o of 5 mil wire and up to 20 v/o of 10 mil wire.

Hot rolled cobalt sheets (0.050 inch) containing 10 20 or 30 volume percent of tungsten wire of either 10 mil, 5 mil or 2 mil diameter and lengths of 1/8 or 1/4 inch in a random pattern were weaker than pure cobalt at room temperature. However, at 2000F, the cobalt sheet containing a random pattern of tungsten wire was approximately twice as strong as pure cobalt sheet.

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